COMPARISON AND ACCURACY ASSESSMENT OF WETLAND LAND COVER CLASSIFICATION SYSTEMS IN THE WILLAMETTE VALLEY, OREGON

by

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A RESEARCH PAPER

submitted to

THE GEOSCIENCES DEPARTMENT

In partial fulfillment of the
requirements for the
degree of

MASTER OF SCIENCE

GEOGRAPHY PROGRAM

January 2002

Directed by
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ACKNOWLEDGEMENTS

I would like to thank my professors, friends and family for helping me with this project. Furthermore, I would like to dedicate my work to the support of two very important people in my life: my graduate advisor and my mother. I don't think it is possible to praise my advisor, Mary Santelmann, enough. My words are inadequate to describe the kindness, understanding, diligence and sincerity she has shown in encouraging me towards my goals. During my times of turmoil, she gave me the motivation to finish; during my times of stress, she was the ear that listened and gave good advice. She is a terrific scientist and was a pleasure to work with. I consider myself extremely lucky to have found the opportunity to be her graduate student. My mother also supported me through her love, caring and understanding.

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COMPARISON AND ACCURACY ASSESSMENT OF WETLAND LAND COVER CLASSIFICATION SYSTEMS IN THE WILLAMETTE VALLEY, OREGON

ABSTRACT: The purpose of this study was to better understand the level of wetland classification consistency among three different land cover layers created using Geographical Information System (GIS) and remote sensor technology. Where inconsistencies in data existed, the goal was to identify the kinds of inconsistencies that occur. The results were focused on wetland land cover classes used for habitat identification and suitability studies. A GIS was used to help manage and combine the data from the three different systems spatially. The different land cover classification systems used were: 1) the Oregon Department of Fish and Wildlife Classification System (ODFW), 2) the National Wetlands Inventory (NWI) and 3) the Pacific Northwest Ecosystem Consortium's Classification (ERC/ARA). Digital orthophotos and site visits were used to verify the accuracy of a stratified random sample of the areas identified as wetlands by each system. From this verification process inferences about the relative accuracy of each system of classification were made. Data on the 1) total area and frequency of wetland polygons; 2) types of wetlands; 3) spatial agreement; 4) uniquely identified wetlands, and 5) strengths and weaknesses (comparison between verification system classifications and stratified random sample with field verified data) were analyzed and compared for the three land covers.

OVERVIEW

Wetlands function as the kidneys of the ecosystem. They are important in controlling and moderating water quantity, (e.g., for conveying and storing floodwaters) and water quality (trapping sediment, nutrients and toxins) (Larson and Kusler, 1967). They also have numerous other functions such as providing habitat, opportunities for recreation, education, and aesthetic beauty. Definitions of wetlands are important for scientists, managers and more recently for private-land owners who have wetlands on their property (Tiner, 1984). The wetland scientist is concerned with classification, inventory and research on wetlands and has a set of instructions on how these are assessed. Wetland managers are more concerned with policy and laws and how exact the definitions of wetlands can be. The characterization of wetlands, including size, location, and conditions can change greatly from one wetland to another (Tiner, 1984). This factor has caused a great deal of confusion and irregularity in the management, classification and inventory of wetlands (Mitsch and Gosselink, 1993).

Quantitative methods for addressing the problems of classification and assessment of wetlands for managers and scientists are becoming more essential. The spatial and temporal distributions of wetlands over large areas make remote sensing and geographical information systems (GIS) an ideal way to study them (Lyon and McCarthy, 1995). Remote sensor technologies supply inventory data on the extent, type, and land cover of wetlands (Lyon and McCarthy, 1995). GIS technologies provide information that can be used for management of national, regional, local and individual sites. The capability to evaluate future alternatives for wetland management and regulation is a valuable tool for inventory and monitoring of wetlands (Lyon and McCarthy, 1995). Classification systems and land cover data are integral for models developed to evaluate restoration and development alternatives.

The purpose of this study was to better understand the level of wetland classification consistency among three different land cover classification systems created using GIS and remotely sensed data. Where inconsistencies in data existed, the goal was to identify and understand the kinds of inconsistencies. The results were focused on improving our understanding of wetland land cover classes used for habitat identification and suitability studies for eventual use in evaluation of restoration alternatives being considered for implementation by watershed councils in Oregon.

Large-scale habitat studies focus on suitability of land cover classes. It is beyond the scope of most metapopulation modeling studies to concentrate on wetland habitat identification, yet wetland habitat can be critical for many species. Land cover analysis can be a suitable alternative to in-depth study of each individual wetland site. The type and accuracy of the classification systems used have a direct bearing on the usefulness of land cover systems for habitat suitability modeling. It is important to know the strengths and weaknesses of land cover classifications systems available for identification of wetland habitat to improve spatial modeling.

This work supported a second project, “Developing Methods and Tools for Watershed Restoration”, lead by John Bolte (Oregon State University, OSU), with wildlife analyses being conducted by Mary Santelmann (OSU). The goals of the project were to create a GIS-based decision tool for generating and evaluating restoration strategies consistent with stakeholder goals. The approach encompassed integrating models of hydrology, water quality, biodiversity, and habitat quality at the watershed scale, socio-economic analyses of stakeholder constraints on feasible restoration options, and economic analyses of restoration options. This multi-objective model relies heavily on GIS land cover layer classification developed by the PNW-ERC (Cohen, 1999). The location, extent and type of wetlands in the land cover data were particularly significant for the wildlife habitat suitability portion of the model. Concerns existed over the adequacy of wetland classes identified by the PNW-ERC classification, in particular whether there were systematic errors that resulted in under-estimation of certain wetland types (e.g., forested wetlands and shrub-scrub wetlands) as well as other potential errors in classification of wetlands.

The PNW-ERC classification was used to generate a habitat classification system called the ARA (Adamus, *et al.*, 2000). This ERC/ARA classification system (Figure 3 and Table 3) was further altered to define more wetland classes by adding in a small stream coverage and wet shrub coverage (discussed in the data section).

Two other wetland classification systems were considered for the study on watershed restoration tools. The most readily available and widely used wetland classification system, the National Wetland Inventory (NWI), was used for part of the comparison in this study (Figure 2 and Table 4). The NWI system is focused on large-scale, general location information about wetlands. Another classification system readily available in the study area was the Oregon Department of Fish and Wildlife (ODFW) land cover/land classification system (Figure 4 and Table 2). This system was developed for land managers, biologists, and the general public for many uses including: assessing wildlife information, performing ecosystem and landscape assessments, and identifying restoration areas (ODFW, 1998). The ODFW and NWI systems use vegetation physiognomy and landscape position (i.e., riparian or depressional) to determine classes. Whereas the ERC/ARA wetlands are generally not shrub or tree dominated so they are mostly described by presence of seasonal or permanent water except where the wet shrub class was created using ancillary hydric soils data. Each of the classification systems for the study site contained a predominant type of wetland. The NWI was focused on Palustine wetlands, whereas the ERC/ARA was predominantly wet shrub. The ODFW system contained the most forested wetlands of any of the classification systems.

A comparison of the skill of the NWI and ODFW systems at locating and identifying wetlands when compared with the PNW-ERC classification system was important for the modeling generated by the study. The spatial extent of these two other systems was not large enough to cover the entire study area for the watershed restoration tool. However, these data sets are currently being updated and expanded and their potential for use in habitat modeling requires an evaluation of their usefulness in identifying and classifying wetlands. A comprehensive, consistent way to identify wetlands from regionally available data is of great importance to scientists, managers and the general public.

To determine the level of consistency among the various wetland data sets, the total acreage in the study area each of the data sets classified as wetlands and the acreage of each type of wetland were compared. Although acreage comparisons are important for evaluating total wetland projections, this type of comparison is an inadequate indicator of consistency. The various data sets may classify different areas as wetlands even though the total acreage of wetlands maybe similar. To resolve this problem, this study utilized a GIS to combine the different land cover classification systems and generate tabular data summaries showing areas of agreement and disagreement. Of particular importance was the abundance of forested wetland classifications in NWI and ODFW, but absence of a classification category for forested wetlands in the ERC/ARA, as this is generally recognized as the most difficult wetland type to map (Shapiro, 1995). Tests to determine the relative strengths and weaknesses of wetland land cover classes were difficult because there was no standard wetland classification system with which to compare the various data sets.

The inconsistencies among the classification systems were not easily resolved. To clarify our comparisons, a set of 12 new classes comparable for all systems was generated (Table 5). These verification system classes were based on three characteristics of wetlands that could be determined from remotely sensed data (orthophotos) and available GIS coverages: 1) vegetation physiognomy (forest, shrub, herbaceous) 2) topology/landscape position (riparian or not, small depressional or extensive slope/flat) and 3) degree of wetness (permanent/seasonal). These verification system classes were verified on digital orthophotos and with site visits and used to "truth" the other systems and generate tabular information on classification disagreements.

To obtain independent information on whether a site was actually a wetland and degree of accuracy of the various classification systems, the existing data set was randomly sampled. Polygons identified as wetlands by all three systems of classification were located on orthophotos, and from these, 10% were randomly selected in a stratified random sampling of the orthophoto (885 sites randomly sampled from 8850 total wetland sites in the study area). The sampling was stratified with the original data set by total area and frequency for the combined systems (Figure 5). An extension for the ESRI ArcView© program from Quantitative Decisions called Simple Random Sample© was used to generate a 10% sample of the polygons classified as wetlands. The sample was well stratified with the complete data set (Figure 5) in each of the classification systems for both total area and polygon frequency. The areas selected by the sampling were overlaid on digital orthophotography and classified (or "truthed") as one of the 12 wetland types of verification system classes. Additionally, on difficult classifications, field visits were made to 10% of the stratified random sample to collect data in the form of digital photographs assigned to specific GPS locations. This information was used to evaluate and interpret the wetland type and to assign the "truthing" classification (referred to as the verification system classification). Tabular data sets of the strengths and weaknesses of the different classification systems were compared to the field verified "truthing" classes (Table 5).

This research was designed to provide general comparative information about the accuracy of available wetland coverages and to identify possible patterns among the data sets. The results were focused on identification of data sets most suitable for use in habitat relationship models, and understanding the extent and nature of potential errors in the various existing classification systems.

DESCRIPTIONS OF TECHNIQUES USED AND METHODOLOGY

The research focused on part of the Long Tom Watershed, south of Corvallis and northwest of Eugene, Oregon (Figure 1). The study region was selected for its rural and urban interfaces with wetlands and the maximum extent of available orthophoto and land cover data. This area is also representative of the features, topography, and land cover found elsewhere in the Willamette Valley.

The comparison of wetland land classification systems involves (1) collecting relevant data; (2) assembling the data into a GIS, and (3) analyzing the data.

1. Data

Data for the wetland land class layers were obtained from three different sources. The National Wetland Inventory (NWI) data layers were acquired from the U.S. Fish and Wildlife Service (Figure 2 and Table 4). The NWI maps are compiled through manual photointerpretation (using Cartographic Engineering 4x Mirror Stereoscopes) from the National Aerial Photography (NAPP) or National High Altitude Photography (NHAP) aerial photography supplemented by Soil Surveys and field checking of wetland photosignatures. Delineated wetland boundaries are manually transferred from interpreted photos to USGS 7.5-minute (1:24,000 scale) topographic quadrangle maps and then manually labeled. The NWI was developed to determine the distribution, extent, and quality of the remaining wetlands in relation to their value as wildlife habitat (Shaw and Fredine, 1956). The uses of the NWI are clearly defined as not delineating legal boundaries of wetlands for regulatory purposes. Instead, the scope of the NWI is for large-scale, general location, distributional information about wetlands.

The Pacific Northwest Ecosystem Research Consortium (PNW-ERC) Coverage was developed to analyze basin wide and watershed-scale changes in land use and wildlife responses over time (Figure 3 and Table 3). The land use/land cover map was generated through digital image processing of multi-seasonal thematic mapper Landsat TM imagery from 1992 and 1993. Relative radiometric normalization to a common image was performed to correlate the information on the different dates. A tasseled cap transformation was used to save file space and for ease of physical interpretation. A reference data set from aerial photographs & GIS coverages was done for error checking and training site information (Cohen, W., 1999). The original land cover classes were compiled into different classes (called ARA classes) based on habitat suitability (Adamus, *et al.*, 2000).

Oregon Department of Fish and Wildlife (ODFW) land cover/land class data layers for the Willamette Valley area were constructed by making mylar manuscripts from USGS Orthophotos and Topographic maps (Figure 4 and Table 2). These maps were updated by using the 1993 ODFW-WAC Willamette Valley color serial photo set. The natural vegetation and agricultural areas were separated by color, shading, leaf development, and ground moisture content. The polygons were identified by traveling only on public roads (no private access was sought). 90% of the polygons were identified from the field and the remaining from the color aerial photographs. The accuracy assessment used stratified random sampling points of each cover type, which produced an overall accuracy of 81% (ODFW, 1998).

The orthophotos used for assignment of polygons to the 12-category classification system (verification classification system) were obtained from USGS Data Center and the primary source data was from aerial photographs taken May 7, 1994. Orthophoto-quadrangles (DOQ) are black and white, 3.75 minutes of latitude by 3.75 minutes of longitude images cast on the UTM projection of the North American Datum of 1983 (NAD83). These orthophotos were used for the investigation and analysis of wetland accuracy of the existing coverages.

2. Assembling the data

Data acquisition and formatting were an integral part of the project. A considerable amount of time was spent fitting the data layers to the same projection. The projection used for this study was UTM, Zone 10, NAD83, meters, because the larger project utilizes data in this projection. Some error results from transforming data from one projection to another. This is particularly true when moving from NAD27 to NAD83. The ERC data layer was re-projected from UTM NAD27 to NAD83 using ArcInfo®'s projection function. The ODFW data layer was re-projected from Lambert NAD 83.

The ERC/ARA layer, originally acquired in raster format, was converted to a polygon data set for use in the habitat modeling. Small streams were burned into the land coverage by buffering a vector small stream coverage by 15 meters on each side. To generate a wet shrub class, the natural shrub class was overlaid with a hydric soils type D layer and the natural shrub polygons that intersected type D hydric soils became wet shrub.

The data for each of the classification systems was combined in an ordinal map that portrayed each of the layers merged (National Wetlands Inventory: NWI, Oregon Department of Fish and Wildlife: ODFW, and Pacific Northwest Research Consortium modified layer: ERC/ARA) (Figure 5). This map was used to find tabular acreage and polygon frequency data for the comparison of the wetlands. The data portrayed polygons that each classification system, or a combination of classification systems, identified as wetlands. The area totals for each combination were recorded and used for the stratification of the sampling. Area of wetlands of each system and the number of polygons or frequency of wetlands was similar when a random 10% of the population was sampled (Figures 5).

Each land cover had a different classification system and this made comparisons of the relative strengths and weaknesses of the data sets difficult. A classification or crosswalk of the different classifications was developed to assist with determining the level of consistency among the data sets (Table 5). This classification verification system was developed to help compare the wetland coverages.

To obtain independent information on whether a site was actually a wetland, the sample data set was overlaid on digital orthophotos. Each sample polygon was assigned to one of the verification system classes, or labeled too difficult to identify from the photos. These areas, as well as a random sample of the polygons classified as wetlands of a given type from the orthophotos, were investigated in the field. Observations from the ground were made with the assistance of a GPS location of the lat/long coordinates and each site was photographed with a digital camera. These data were assimilated into the tabular information and an analysis of the consistency between classification systems was performed (Tables 8-13).

3. Analysis

The analysis of the wetland land cover classifications was designed to provide information on two primary issues: (1) the level of consistency among the three, wetland data sets and (2) the relative strengths and weaknesses among the data sets.

Total Area and Frequency of Polygons

In the study, we first compared the total acreage and number of polygons each data set classified as a wetland in the study area to determine the level of consistency among the various data sets (Table 1, Figures 6 and 7).

Types of Wetlands

This comparison was expanded to evaluate the acreage that each data set classifies within various systems or subcategories of wetlands (Figures 2-4 and Tables 2-4).

Spatial Agreement

Although the acreage estimates may be close (as with ERC/ARA and ODFW), actual locations of areas determined by the coverages to be wetlands may be inconsistent. The ordinal map showed locational agreement/disagreement between the different types of wetlands (Figure 5). It easily portrays where all three systems agree the area is a wetland, or the consistency of locating wetlands.

Uniquely identified wetlands and Strengths and Weaknesses

However, further information on the type of wetlands each classification used was needed to investigate the relative advantages and disadvantages of the systems. To resolve this problem, a portion of the polygons determined to be wetlands by any of the classification systems was randomly sampled. The random sample of 10% of the total polygons identified as wetlands was stratified by both area and frequency of the ordinal or combined systems (7 strata for area and 7 strata for frequency). From the 10% stratified random sample, the orthophotography and ground investigations were used to place verification system class codes in the existing wetland identified polygons (Figures 8 and 9). Each of the classification systems found wetland areas the other systems did not identify. These uniquely classified wetlands were totaled per classification system and analyzed (Figures 10-11 and Tables 6-7). These verification system classes were compared with the existing classifications of each system on a type-by-type basis (Tables 8-13). This analysis helped identify areas where the original classification was inconsistent. Strengths and weaknesses of the classification systems were derived from these analyses.

RESULTS

The analysis of the data derived five methods for comparison: 1) total area and frequency of wetland polygons 2) types of wetlands; 3) spatial agreement; 4) uniquely identified wetlands; and 5) strengths and weaknesses.

Total Area and Frequency

Looking at total wetland acreage was dependent on the methods of classification for each of the systems. The ODFW Classification had the lowest number of polygons and total area. The ERC/ARA Classification system contained the most wetland-identified polygons. The NWI system found more total area of wetlands than either ERC/ARA or ODFW (125,000,000 m^2, 100,000,000 m^2, and 15,000,000 m^2 respectively) (Table 1, Figures 6 and 7). The large apparent disagreement in total area between ERC/ARA and ODFW is explained partly by the different mission responsibilities of the data sets and the techniques used to classify wetlands.

Types of wetlands

Although NWI had the greatest area of wetlands, ERC/ARA had the highest frequency of polygons, when comparing the area of wetlands. Frequency for the ERC/ARA classes was high due to the wet shrub and small stream classes generated in the ERC/ARA system. These two classes generated many small polygons. Polygon frequency for each of the classification systems correlated well with the wetland area when each system was looked at independently (Tables 2-4, Figures 2-4). The frequency discrepancies were found in both ODFW, which had a proportionally greater amount of water class polygons, and the NWI system, which had a comparatively larger amount of Riverine polygons, over 800 polygons, than wetland area (700 hectares) would indicate (Figures 2-4).

A simple comparison of the wetland classes for each system shows a predominance of the wet shrub (6,000 hectares area from 3000 polygons) for the ERC/ARA system. This system has no way to correctly identify forested wetland areas and the forested wetlands found in field sample were probably misclassified as wet shrub (Figure 3). The ERC/ARA system does identify different forest types, but has no way to differentiate wetland forests from other forest types. The NWI system identified the most wetland area in the Palustrine Forested – Seasonally Flooded (PFOC) class (Figure 2). It also found mostly Palustrine Emergent – Seasonally or Semi-permanently flooded wetland. Furthermore, ODFW showed a high proportion of Ash-Cottonwood-bottomland pasture mosaic and more water classes than either of the other classification systems (Figure 4).

Spatial agreement

The wetland acreage comparisons are useful as a general indicator of the tendency of the various data sets to classify areas as wetlands. However, they do not provide information on the extent to which the various data sets classify the same areas as wetlands. The merged map and charts (Figure 5) showed that all three systems seldom agree upon classification of a given polygon as a wetland (under 10 percent of the time). In more than 70% of the polygons of wetlands found only one system identified the area as a wetland.

Uniquely identified wetlands

Comparing inconsistencies among different systems required making a crosswalk of the different classes and formulating a verification classification system that could include all wetlands classes of all systems. These verification system classes were applied to the areas identified in a random sample of the data set by overlaying the merged map on orthophotos. The random sample was well stratified with the original data in both total area and number of polygons for the combined systems (Figure 5). There is little difference between the proportional area in each class of the study data set and the 10% random sample (Figure 5). Frequency of polygons showed related similarity (Figure 5).

The polygons from the stratified random sampling were assigned classes from the verification classification system using aerial orthophotographs and studies of sample sites in the field. The data were calculated as the totals found in the field and analyzed before the comparison with the original classification system. The analysis of the verification classes assigned to the random sample revealed more seasonal wetlands, riparian forest and forested depressional classes identified (Figures 8 and 9). This indicates the study area contains mostly these classes and the other analysis should corroborate this conclusion. It is interesting to note the frequency does not fit well with the area totals. The frequency of occurrence of polygons of both riparian forest and seasonal wetland classes are proportionally lower than their area totals. These wetland types tend to occur as larger polygons with more area. Some of the smaller area totals had a higher frequency of occurrence, such as the lake and large stream classes. Comparison of the different systems starts with looking at the areas where only one of the systems classified the area as a wetland (uniquely identified wetlands).

Unique identification of areas as wetlands is high (more than 70%) for all of the classification systems (Figure 5). The uniquely identified wetland area total for the NWI system was particularly high, as would be expected since NWI also identifies more area wetlands compared to the other systems (Figures 5 and 6). ERC/ARA and NWI were in the most agreement when looking at the comparison on the merged map (Figure 5). This is of particular interest because the ERC/ARA system does not identify forested wetland classes, whereas NWI does identify them. The assignment of the verification system classes is independent of what each system classifies the area. In the case of the ERC/ARA system, even though this system does not identify wetlands, the verification system classification of the stratified random sample shows NWI having some forested wetland area. This inconsistency can be explained through misclassification, probably due to the forested wetlands being classified as wet shrub in the ERC/ARA system. These classes are difficult for the remote sensing technology to differentiate.

The abundance of uniquely identified wetland polygons implies that much of the apparent inconsistency occurs in areas where one classification system disagrees with the others in what is determined to be a wetland (Tables 6 and 7, Figures 10 and 11). For example, seasonal wetlands comprise the greatest proportion of wetlands in the study region in percent area according to the ERC/ARA and NWI systems. The frequency of polygons for seasonal wetlands from the verification system classes indicated ERC/ARA found the greatest percentage of polygons of this type. On the orthophotos it was difficult to differentiate between cropland and seasonal wetlands. Some overestimation of this class would logically occur. Frequency of wetland polygons identified in the verification system classes for the ERC/ARA system was high partly due to the wet shrub and small stream classes generated in the ERC/ARA system. These two classes generated many small polygons of seasonal wetland and wet shrub verification system classes. This will be discussed further in conjunction with the consistency evaluation. ODFW found more riparian forest wetland areas than the other classes (41%, where ERC/ARA found 11% and NWI found 1%).

The crosswalk for the riparian forested verification system class contains cottonwood, ash-cottonwood-bottomland and pasture mosaic land classes from ODFW and riverine classes from the NWI. Riverine is wetland closer to the stream than cottonwood or bottomland wetlands and this could be one reason for ODFW to be a better identifier of riparian, forested wetlands. The NWI system has no way to consistently differentiate upland forested areas from forested wetland classes and thus tends to identify less forested wetland area. The ERC/ARA sytem is completely biased against identification of forested wetlands.

The amount and frequency of forested depression class wetlands from the verification system classifications is quite comparable among each of the classification systems. Riparian shrub wetlands were identified more commonly by ERC/ARA and ODFW than by NWI. The likely explanation for this dissimilarity is that the riparian shrub verification class usually identified by NWI as the riverine class. This NWI class is not extensive and only includes those areas near stream or river systems.

One reason for the greater consistency in wetland classification between our stratified random sample of wetlands from the orthophotos and the NWI is that the NWI land classification was based on aerial photography. Satellite data (e.g., the ERC/ARA) cannot match the accuracy of aerial extent, classification detail, or reliability that can be extracted from conventional aerial photography using manual photo-interpretation techniques, such as those used by the NWI project (Shapiro, 1995).

CONCLUSIONS

The results of this study suggest two principal hypotheses for further study: (1) there is significant disagreement in wetland classification among the three wetland data sets; and (2) there are substantial differences in the strengths and weaknesses of the wetland data sets evaluated. These strengths and weaknesses relate both to the effectiveness of the data sets to identify wetland areas as wetlands and to identify the wetland type. The results reported in this paper are derived from a case study in the northern 1/3 of the watershed; additional data and analysis would be required to evaluate these hypotheses conclusively for the entire watershed. The issues raised in this study merit attention and analysis beyond the scope of this report.

1. Disagreement

The land cover classification systems found different wetland types, abundance, and area. Comparisons of the systems comprise measurements of area and frequency of polygons of the different types of wetlands as well as comparison of wetland locations. These measurements were performed on the land classification layers and later compared with actual measurements in the field.

Total Area and Frequency

The area and frequency of polygons of each of the classification systems were totaled for the entire study area. Assessment of the total area of the different classification system layers shows NWI finding the greatest area of wetlands (40% of total wetland area) and ODFW finding the least (26%) . The ERC/ARA system found the most wetland polygons (frequency 41% of total polygons) and ODFW found the least (frequency 27%) . The results from the study indicate that the ODFW system is more conservative in finding wetlands than are NWI or ERC/ARA classification systems (Table 1). This is not surprising because data for the different systems were collected for different purposes. The NWI system was expected to find the most wetlands because the intention for its creation was to determine wetland area (Cowardin, 1979). The ERC/ARA classification system found a great deal of small polygons of class 15 wet shrub and this increased the total area and polygon frequency. ODFW had larger, predominantly forested class polygons and this made polygon frequency numbers lower. Little definitive information is gleaned from simply looking at area and frequency totals for all wetland types.

Discrepancies between classification systems can occur for a number of reasons. For example, some discrepancies are built into the classification systems themselves because certain wetland types are not identified. The lack of any forested wetland classes in the ERC/ARA classification system precludes the identification of this wetland type in that system. Similarly, small streams are identified in the ERC/ARA but not the NWI. Another reason for discrepancies may be the age of the data source for the data sets. Wetland drainage and loss in years intervening between the development of a database and the present may account for some of the discrepancies between NWI (~20 years old) and ERC/ARA and ODFW classification systems. A third reason for discrepancies may be related to the age of the coverage – differences in wetland type identified. Some of these differences may simply reflect vegetation change over time, or they may be the result of misclassification by one system or another. Lack of accuracy in registration of the data sets can account for some discrepancies; and finally, difficulty in identification of some wetland types from remotely sensed data (e.g., seasonal wetlands and forested wetlands) may account for additional discrepancies among systems.

Types of Wetlands

A closer look at the types of wetlands each classification system layer identified is important to find where discrepancies occur. Looking at each system individually shows that the total area and frequency of each type of wetland class was dissimilar from system to system (Figures 2-4 and Tables 2-4). For example, NWI indicates most of the wetlands in the study area are classified as palustrine with some riverine classes found, whereas the ERC/ARA indicates that most wetlands in the study area are wet shrub.

The map and tables (Figure 2) show the Long Tom River was identified in the large streams class, but none of the small streams found with the ERC/ARA system were identified by NWI. Frequency of the different NWI classes fit well with the area totals of each of these classes except for one class. Riverine polygon frequency was proportionately very large. The ERC/ARA system also had a proportionately large polygon frequency for small and large streams. These data were consistent with the ODFW polygon frequency for its water class and warranted a closer look. The greater frequencies in polygon numbers were a product of the generation of the small stream class for the ERC/ARA classification system. These small streams were created from a vector overlay that was buffered to 15 meters. This buffered coverage was then burned into the original ERC/ARA coverage. Places that had not been small streams were turned into the small stream classification, including those areas next to the very pixilated large streams. The ERC/ARA system was originally a raster or grid coverage and; therefore, the large streams were not linear, but blocky. When overlaid with a vector coverage, wedges of small stream that didn't fit into the large stream polygons were created. This artifact of the GIS process used to identify small streams was identified and corrected in the later models utilizing this classification system.

The ERC/ARA land cover classification system was developed to analyze basin wide and watershed-scale changes in wildlife responses over time and surprisingly has no way to differentiate between forested areas and forested wetlands. Additional study including the forested ERC/ARA classes and how well they fit with wetland areas classified by the other systems warrants attention. A proposed system that might alleviate some of this difficulty would define wet forest by selecting forested classes overlaid with NWI classes.

The ODFW system found more area of forested classes and had more polygons of forest and water than other classes in the system. The ODFW was created by the Fish and Wildlife Service and had a enhanced way of differentiating forested wetlands, in this case Ash – Cottonwood – Bottomland, from other forest types. The areas for each of these identified wetland forests was large and this was a relic of the way the ODFW classification was developed. Polygons of any size were drawn from Mylar sheets overlaid on orthophotos. This system differs greatly from the ERC/ARA system based primarily on satellite (TM) Imagery. NWI's approach is much closer to the ODFW.

These differences in wetland classification system were recognized and incorporated into the verification classification system. A distinction between riparian and forested wetland types was appropriate for the habitat scope of this study. Differences between the small streams and large streams were difficult to determine and probably should have been combined into one class in the verification classification system. Non-wetland and Heterogeneous classes were not expected to contain much data as all of the land area in the study site was not included in the data. Only areas identified as wetland by at least one of the different systems were sampled. How well the separate classification systems fit with the verification classification system is discussed under data inconsistency.

Spatial Agreement

Combining the layers of the classification systems shows locations where the systems agreed and disagreed. The three data sets disagree in wetland area determination more than 70% of the time (Figure 5). That is, 70% of the total area identified as a wetland by any one system is only identified as a wetland by that system (uniquely identified wetlands). This disagreement is not primarily among wetland classes or systems, but rather on the basic question of whether or not an area is a wetland. Conversely, all three systems agree on the wetland area in spatial extent in only 7% of the total wetland area found. This large disagreement can be partially explained by areas where only one system identified the area as a wetland (uniquely identified wetlands).

2. Strengths and Weaknesses

Classification system strengths and weaknesses of the orthophoto sampling study were measured by 1) how well the wetland classification found wetlands (i.e., uniquely identified wetlands) and 2) how well the wetland classification system found the correct wetland type compared with the verification classification system using orthophotos and site visits.

Uniquely identified wetlands

Utilizing the verification classification system, digital orthophotos and site visits, the uniquely identified wetlands of the sample were reported as a percent of the total wetland area found for each system in the verification system classification.

The areas where one of the systems did not agree with the others were clipped and annotated for the class in the verification system class system each one identified. ODFW does the best job of finding additional riparian, forested wetlands. As discussed earlier, ODFW has a higher percentage of forested wetlands identified than either NWI or ERC/ARA. Seasonal wetlands for both the NWI and ERC/ARA were identified a great deal of the time. When the orthophotos were used to identify seasonal wetlands, some overestimation occurred. The seasonal wetlands were abnormally difficult to determine from photos and in most cases warranted study of the site from the ground. Many of the selected polygons were in the center of privately owned agricultural fields and were simply assumed to be seasonal wetlands. Lakes, large streams, and small streams were not identified often in the study. This is congruent with the total numbers of these classes compared to the other classes in the sample study. This information was reflected in the comparison of the classification system with the verification classification systems for inconsistencies.

Strengths and Weaknesses

The percent of wetland area correctly identified by each of the systems is a direct response to their strengths and weaknesses. Percent of correctly identified area was computed as ODFW had 64% correct and in particular classes dealing with forested areas, riparian herbaceous, and seasonal wetlands had the most correctly identified wetlands. The ODFW mostly overestimated water classes as riparian associated classes. These classes would exist close to water. The origin of this discrepancy could have been the slight differences in registration from transformations of the data. The shrub classes were overestimated as forested depression and it was difficult, at times, to differentiate between these classes in the orthophotos and in the field. The forested classes contained the greatest percent correct and were incorrect in the heterogeneous class. The sheer size of the polygons could have easily affected the areas where this class was correct and incorrect. ODFW was strongest when identifying forested wetlands and riparian herbaceous, and seasonal wetlands. Its weakest spots were water classes and riparian shrub differentiation.

The ERC/ARA system was strongest when identifying depressional wet shrub. ERC/ARA's wet shrub class was generated from overlaying the natural shrub class with hydric soils and the product of this was an abundance of wet shrub identified. The results show this classification system was a good indicator of wet shrub and the greatest misclassification for the wet shrub was that the ERC/ARA called areas wet shrub that were actually seasonal wetlands. As indicated previously, wet shrub and seasonal wetlands were easy to misclassify. The percent correct for the ERC/ARA classification system was a low 24.54%. The weaknesses of this system include inability to identify wetland forest areas, and misclassification or under-identification of seasonal wetlands and streams. The stream difficulty most likely resulted from the improper generation of small streams and perchance a registration problem. However, the season wetlands class, in any case, should have had better results. Of the total wetland area in the stratified random sample identified from orthophotos and site visits from the ERC/ARA classification system, less than 1% was *correctly* identified as seasonal wetland by the ERC/ARA system (Table 11). With the exception of the wet shrub class, the ERC/ARA classification system did the worst, by far, in correctly identifying the wetland type when compared to data from the field.

The NWI system had 56% correct total area found as wetlands in the study data set. Strengths included accuracy in identifying seasonal wetlands and water classes. Seasonal wetlands were sometimes misclassified as wet shrub depressional, which is congruent with the other systems and the difficulty in differentiating between these two classes. Surprisingly, lakes and riparian forest classifications were the weaknesses of the NWI classification system. The only class defining lakes was lacustrine and this class was mostly forested depression. NWI may need to revisit their classification system for lakes and riparian forest. Albeit riparian forest is difficult to identify directly from orthophotos as it is assumed riparian if it is within a certain distance of a river or river system. Areas incorrectly classified as wetland when there were actually non-wetland classes were found the least with NWI. This indicates that although this classification doesn't always classify the area as the correct type, it does do a good job of finding areas that are wetlands.

Each classification system had strengths and weakness related to classification accuracy and inaccuracy. Overall, ODFW was the best classification for forested wetlands, NWI was best for seasonal wetlands and ERC/ARA was well suited for finding wet shrub classes. For habitat evaluation purposes ODFW is clearly better suited than ERC/ARA. However, scale is an important issue when dealing with habitat evaluation and ERC/ARA may be better suited in at smaller spatial resolutions. This study does not try to address the scale issue eluded to when considering the size of ODFW polygons compared to the ERC/ARA grid scale of 30x30m pixels. An important outcome of this report was finding the NWI to be a suitable representation of wetlands even if this system classified some of them incorrectly.

Future Plans

Information of the type of inaccuracy that is likely to be associated with a particular wetland data set is important both for interpreting wetland data and for improving the effectiveness of data collection and interpretation efforts. By knowing the strengths and weaknesses associated with a particular data set, users can choose the data set that best suits their needs. Such choices can be based on whether is it is more important to identify every wetland area or to know that the wetlands are classified correctly.

The methodology presented in this study could be applied to other types of land cover classification. Additionally, it seems to be a good indicator of strengths and weaknesses of the different systems. A further study of the steps performed to determine the inconsistencies in the data sets warrants attention and further research.

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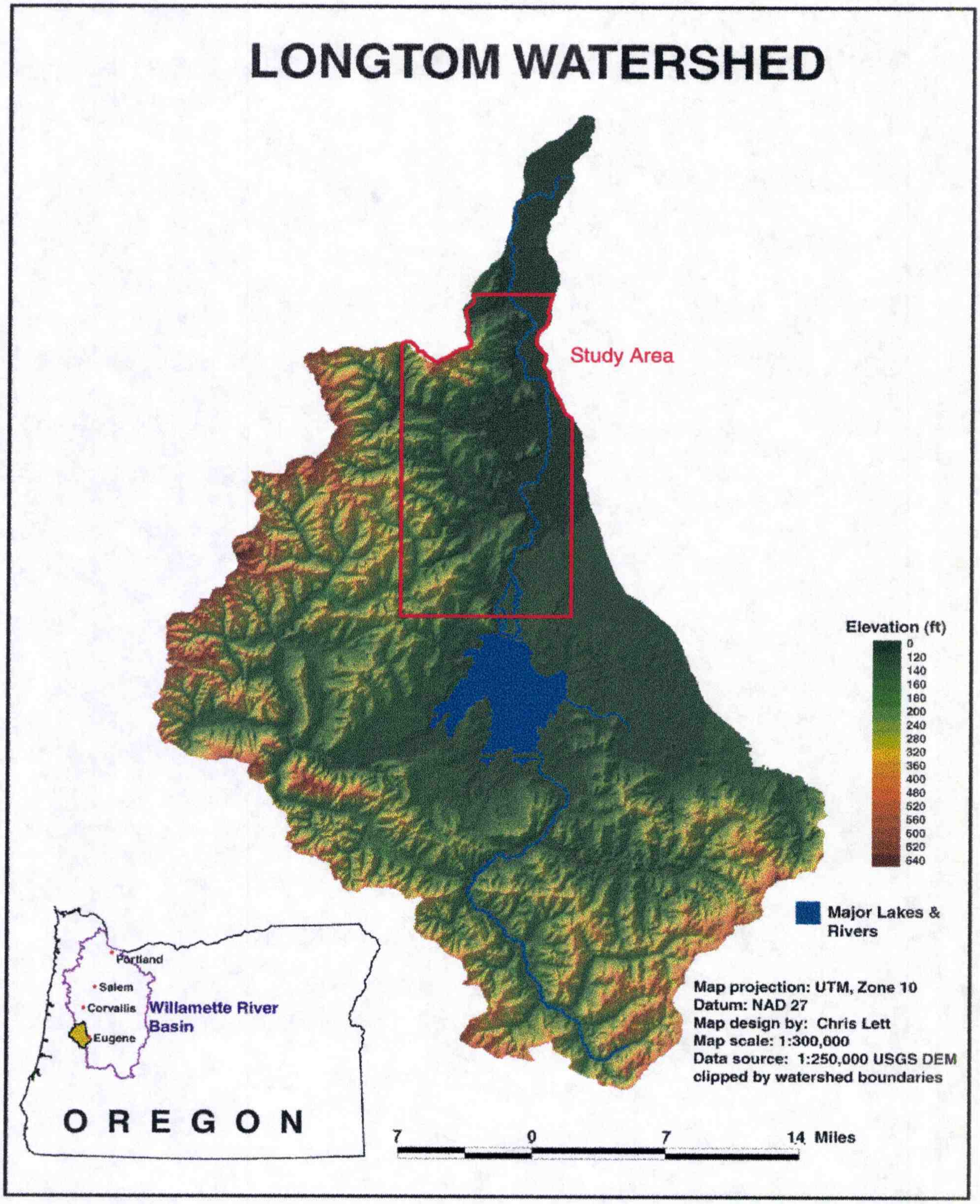

Figure 1. Study site location in the Longtom Watershed in the Willamette Valley, OR.

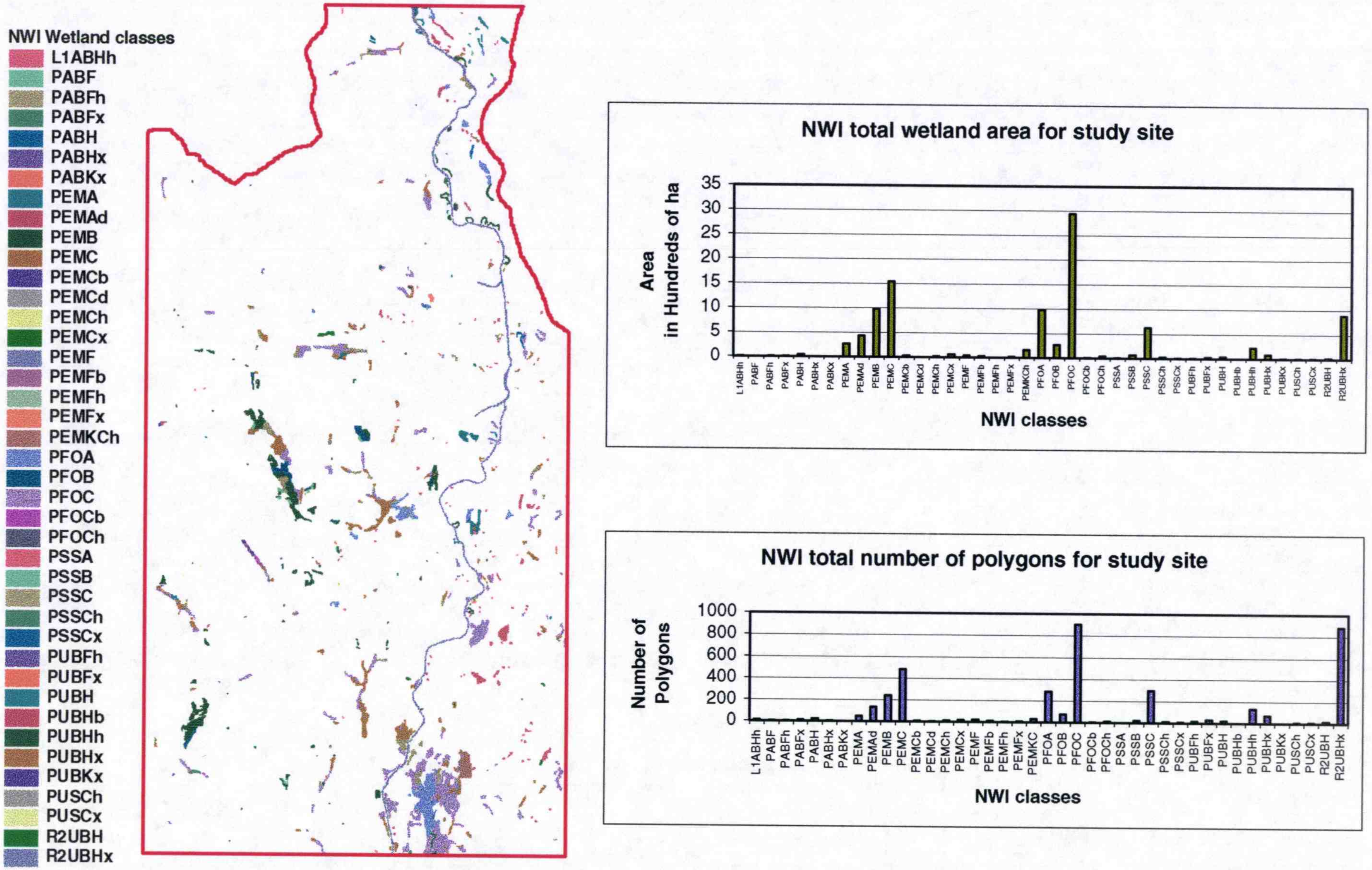

Figure 2: National Wetlands Inventory (NWI) Wetland Classes Map, Frequency and Area Charts. Forested Palustrine classes are the largest area in this system. Riverine area is not proportional to number of polygons for this class (i.e., there are probably small, numerous polygons of the riverine class). This figure corresponds with Table 4.

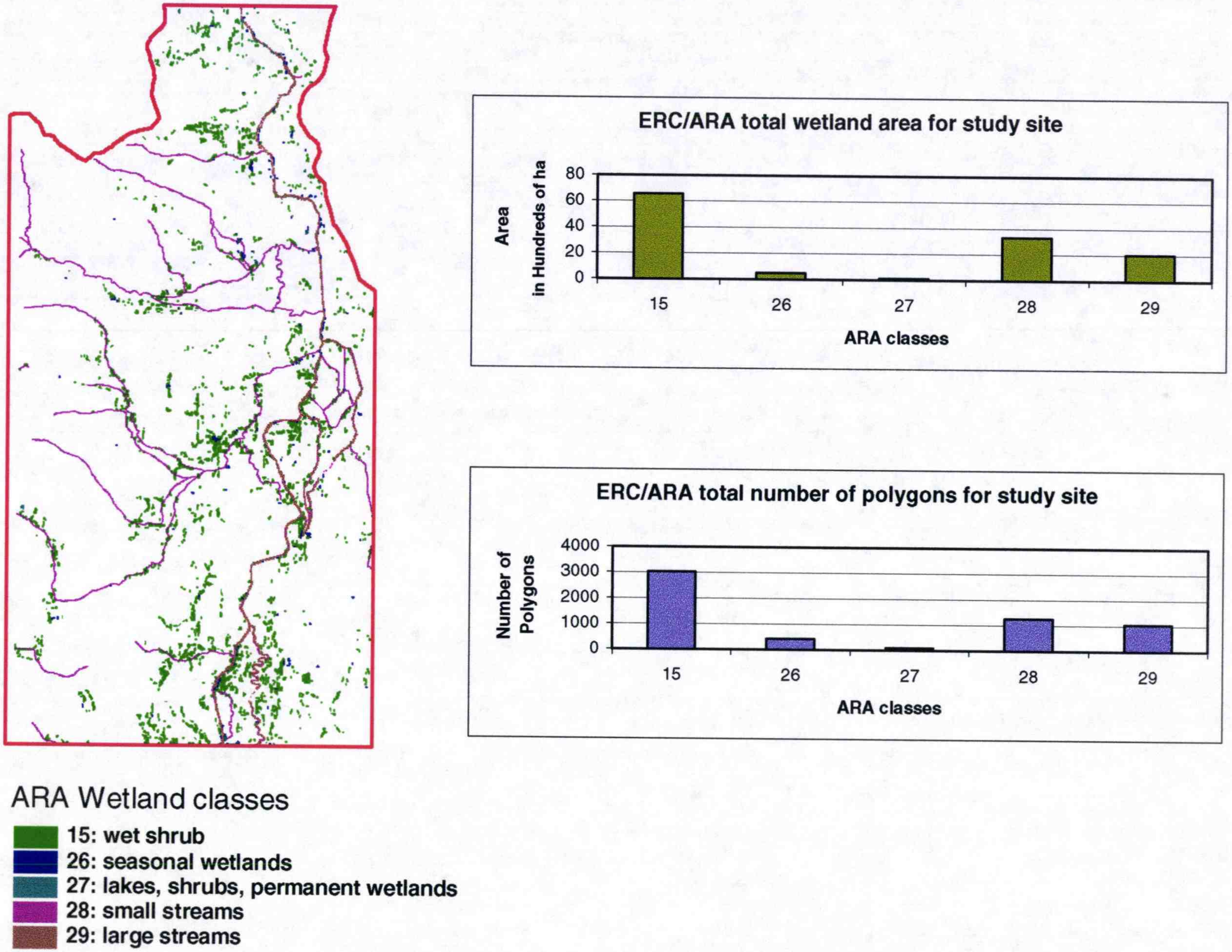

Figure 3: Pacific NW Ecosystem Consortium (ERC/ARA) Wetland Classes Map, Frequency and Area Charts. Notice the ARA system polygons are small and mostly identified as wet shrub classes. Forested wetland classes are absent and small streams are present. This figure corresponds with Table 3.

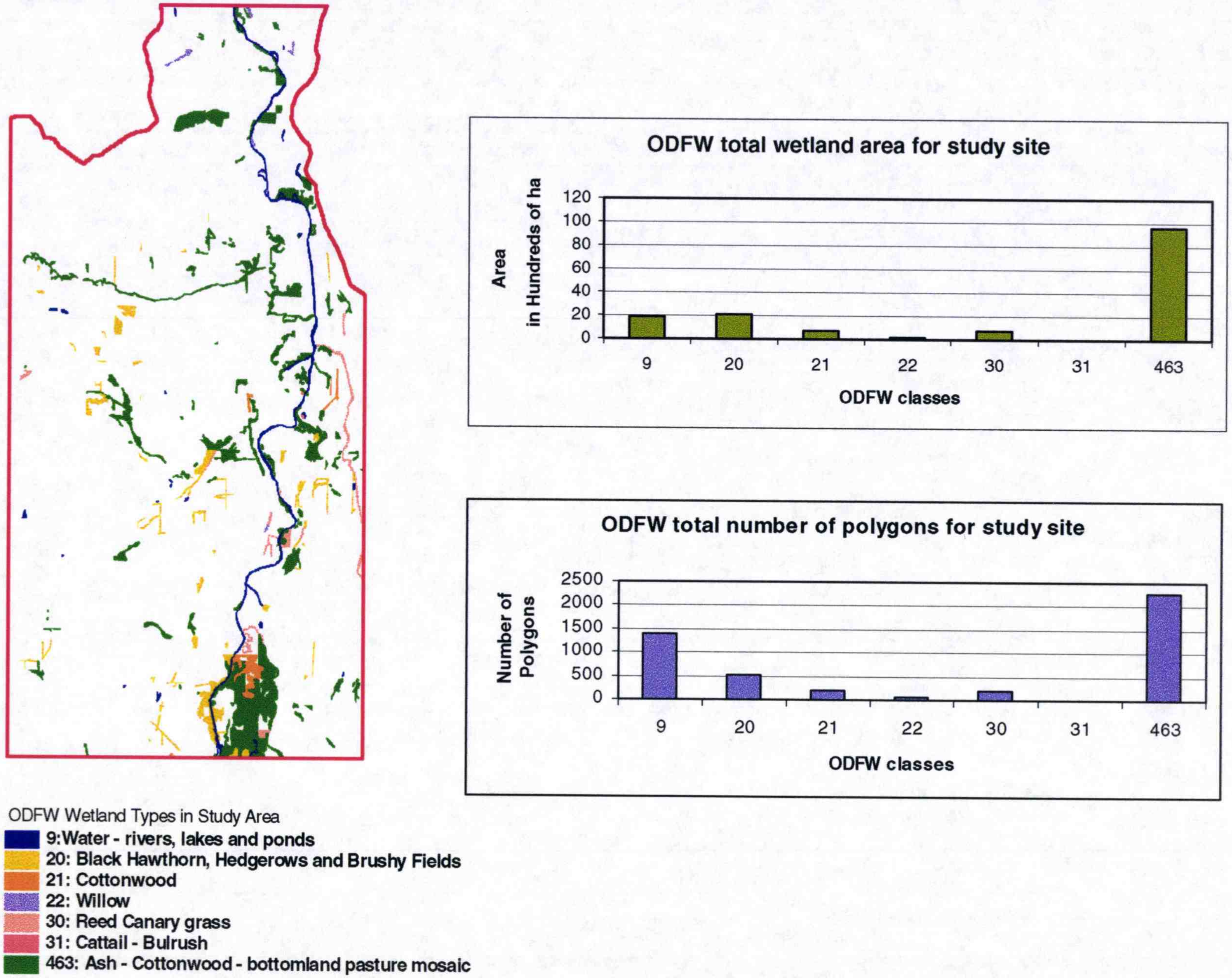

Figure 4: Oregon Department of Fish and Wildlife (ODFW) Wetland Classes Map, Frequency and Area Charts. Notice the ODFW system has a predominance of large polygon sized forested wetland classes. This figure corresponds with Table 2.

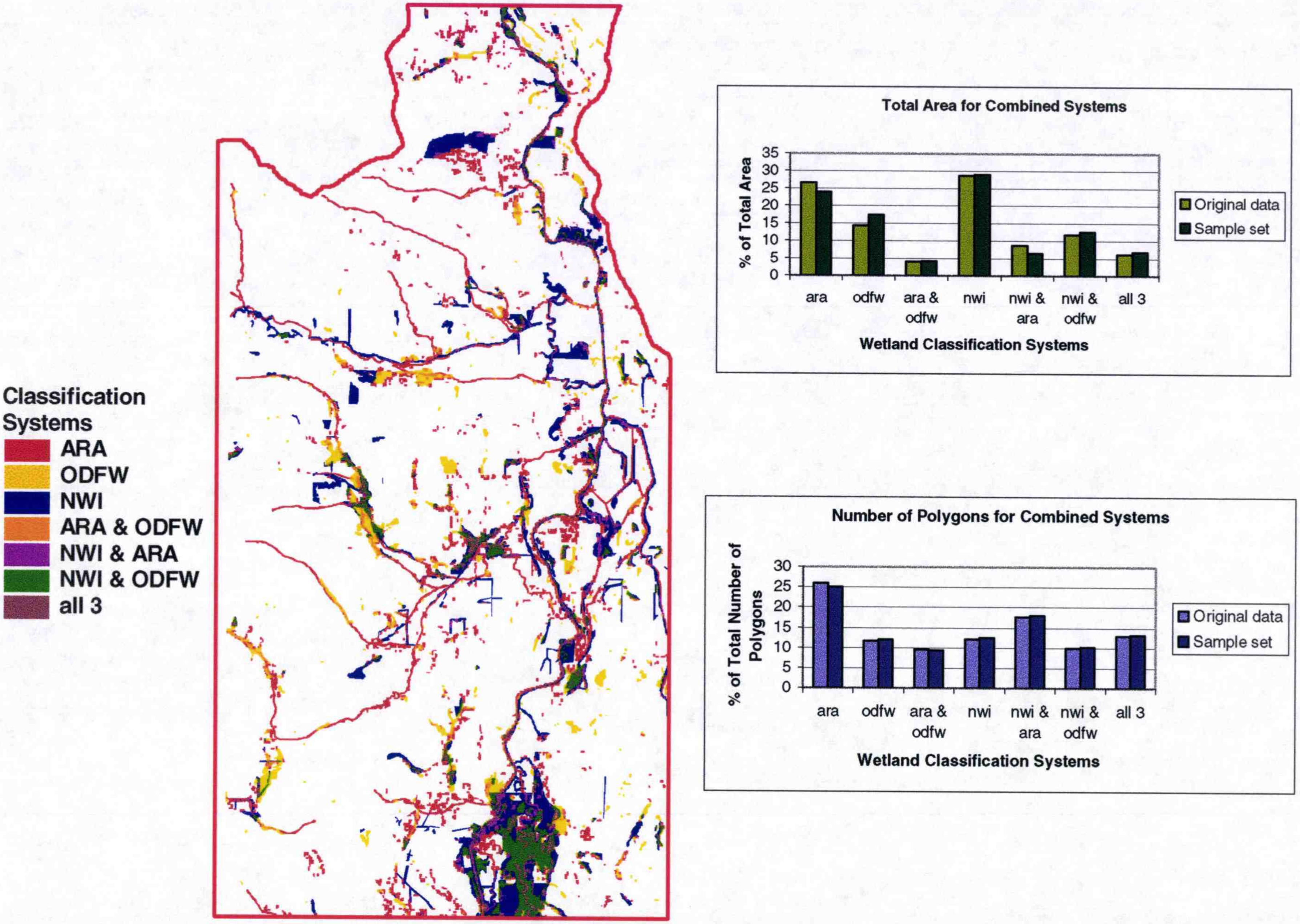

Figure 5: Ordinal merged map of all three classification systems and Area and Frequency Charts. When the systems were combined for analysis of spatial accuracy totals for the area and frequency of polygons were determined (original data). A 10% random sample (sample set) was well stratified with the original data set.

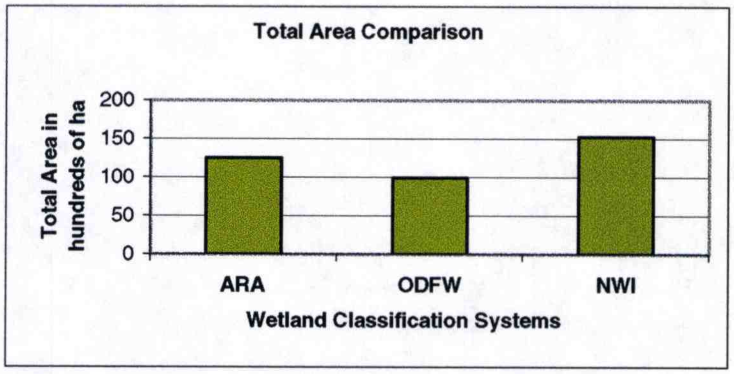

Figure 6: Comparison of the total area of the different classification systems as a test of consistency of the systems to find wetlands. The total area for each system found in the study site was calculated. This figure corresponds with Table 1.

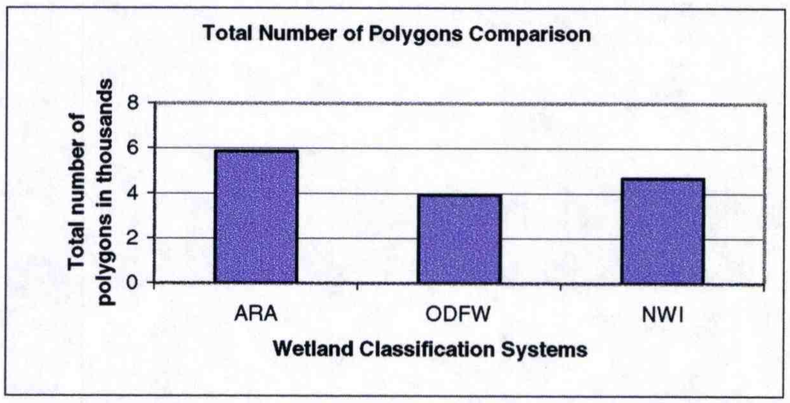

Figure 7: Comparison of the total polygons (or frequency) of the different classification systems as a test of the consistency of the systems to find wetlands. For each system the total number of polygons was calculated for the study site. This figure corresponds with Table 1.

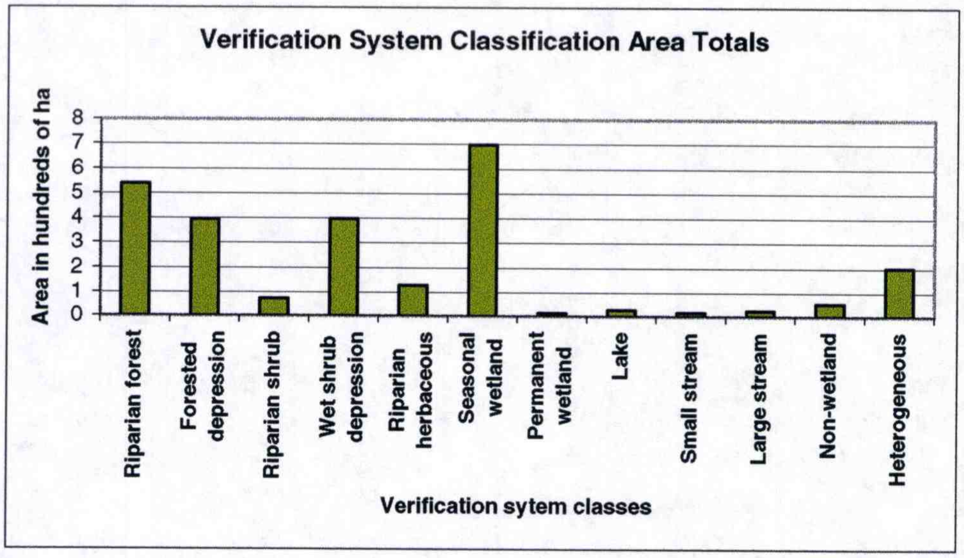

Figure 8: Verification classification system area totals for the sample study. The 10% stratified random sample was overlaid on orthophotos and verified in the field to assign the verification system classes (Table 5). Notice seasonal wetlands and forested are predominant in the study area.

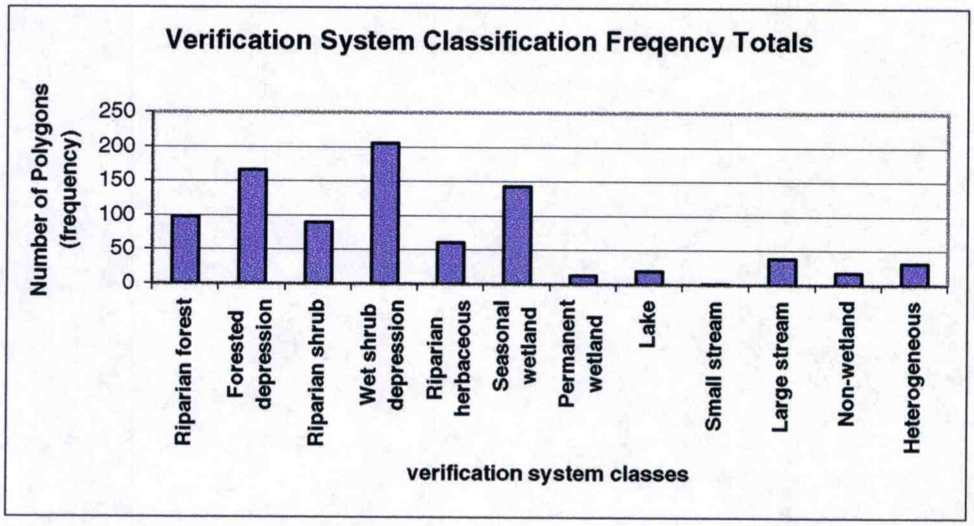

Figure 9: Verification classification system frequency totals for the sample study. The 10% stratified random sample was overlaid on orthophotos and verified in the field to assign the verification system classes. (Table 5).

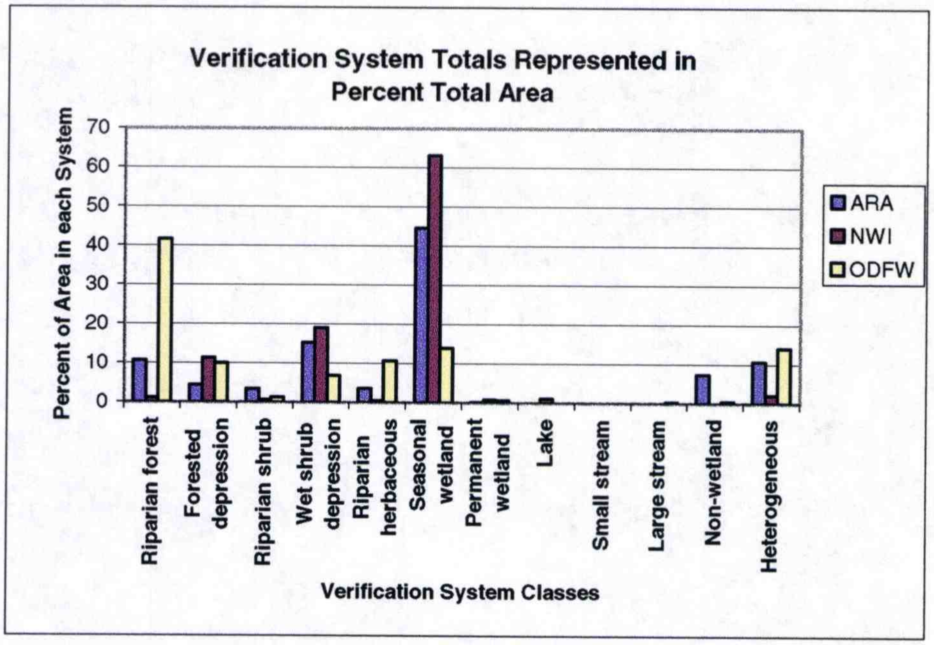

Figure 10: Percent total area each classification system found. When the systems were combined in the ordinal or merged map each system found wetlands the others did not find (uniquely identified wetlands). This graph represents the uniquely identified wetlands independently as the percent total area each system found in the verification system classes. This figure corresponds with Table 6. The NWI system shows some forested classes and this is probably an artifact of misclassification of wet shrub classes.

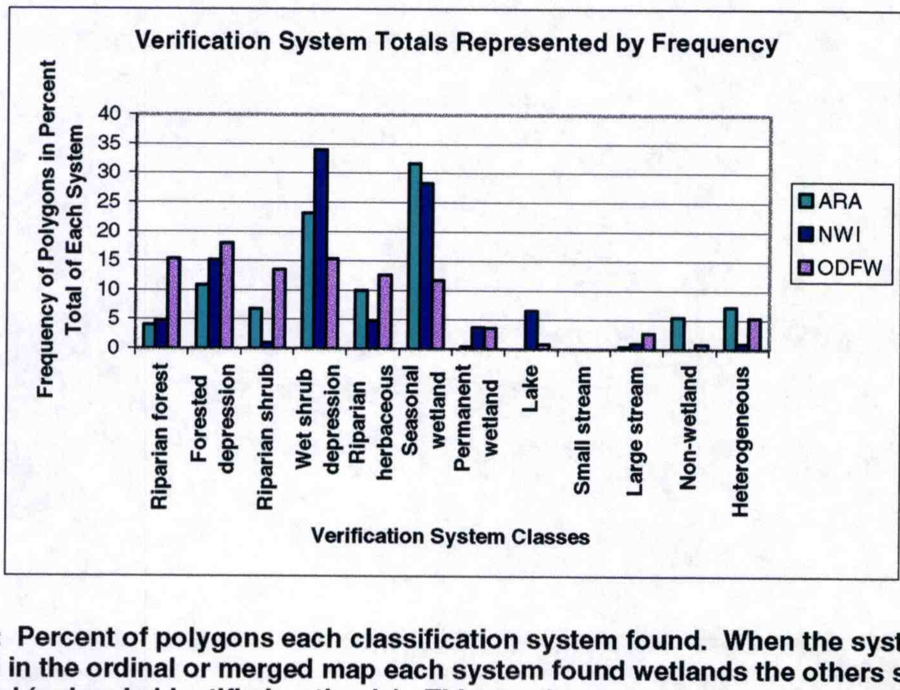

Figure 11: Percent of polygons each classification system found. When the systems were combined in the ordinal or merged map each system found wetlands the others systems did not find (uniquely identified wetlands). This graph represents the uniquely identified wetlands for each system independently as the percent total area each system found in the verification system classes. This figure corresponds with Table 7.

Table 1: Area and frequency totals of wetlands for the three classification systems. Calculated as the total area each system found in the study site. This table corresponds with Figures 6 and 7.

Classification Systems	Freq. Of Polygons	Area in ha	% Total Area	% Frequency
ERC/ARA	5861	12521	33	41
ODFW	3921	9958	26	27
NWI	4666	15220	40	32

Table 2: The ODFW Classification Wetland Area and Frequency Totals. Individual analysis of the ODFW system showed many large polygon size forested classes identified. This table corresponds with Figure 4.

ODFW Code	Frequency	Area in ha	% Frequency	% Area
Water – rivers lakes, & ponds	1400	1875	30	12
Black Hawthorn, Hedgerows & Bushy fields	507	2087	11	14
Cottonwood	189	696	4	5
Willow	81	155	2	1
Reed Canary Grass	204	764	4	5
Cattail – Bulrush	2	9	0	0
Ash – Cottonwood – bottomland pasture mosaic	2283	9635	49	63

Table 3: The ERC/ARA Classification Wetland Area and Frequency Totals. Wet shrub is the predominant class in this system. This table corresponds with Figure 3.

ERC/ARA	Frequency	Area in ha	% Frequency	% Area
Wet shrub	3020	6563	51.53	52.42
Seasonal wetlands	425	482	7.25	3.85
Lakes, shrubs, permanent wetlands	89	101	1.52	0.8
Small streams	1271	3329	21.69	26.58
Large streams	1056	2046	18.02	16.34

Table 4: The NWI classification system area and frequency totals. Palustrine classes were greater than other classes in this system. This table corresponds with Figure 2.

Classes	NWI Code	Frequency	Area in ha	% Frequency	% Area
Lacustrine	L1ABHh	12	11	0.31	0.12
Palustrine	PABF	6	5	0.15	0.05
	PABFh	3	6	0.08	0.06
	PABFx	12	14	0.31	0.14
	PABH	22	42	0.56	0.43
	PABHx	3	3	0.08	0.03
	PABKx	1	3	0.03	0.03
Palustrine - Emergent	PEMA	50	262	1.28	2.63
	PEMAd	131	435	3.34	4.37
	PEMB	240	977	6.12	9.81
	PEMC	485	1541	12.37	15.47
	PEMCb	10	28	0.26	0.28
	PEMCd	5	4	0.13	0.04
	PEMCh	15	19	0.38	0.19
	PEMCx	18	54	0.46	0.54
	PEMF	22	40	0.56	0.4
	PEMFb	15	27	0.38	0.27
	PEMFh	5	2	0.13	0.02
	PEMFx	8	21	0.2	0.21
	PEMKCh	30	156	0.77	1.57
Palustrine – Forested	PFOA	284	981	7.24	9.85
	PFOB	77	266	1.96	2.68
	PFOC	905	2946	23.08	29.58
	PFOCb	3	12	0.08	0.12
	PFOCh	12	38	0.31	0.38
Palustrine – shrub/scrub	PSSA	2	6	0.05	0.06
	PSSB	21	72	0.54	0.72
	PSSC	300	626	7.65	6.29
	PSSCh	15	25	0.38	0.25
	PSSCx	11	7	0.28	0.07
Palustrine – unconsolidated bottomland	PUBFh	19	14	0.48	0.14
	PUBFx	31	30	0.79	0.3
	PUBH	21	36	0.54	0.36
	PUBHb	1	2	0.03	0.02
	PUBHh	131	225	3.34	2.25
	PUBHx	71	85	1.81	0.85
	PUBKx	1	9	0.03	0.09
	PUSCh	10	8	0.26	0.08
	PUSCx	10	6	0.26	0.06
Riverine	R2UBH	18	20	0.46	0.21
	R2UBHx	885	894	22.57	8.98

Table 5. Crosswalk for Verification System Classes. This table corresponds with Figures 8 and 9.

New Code	Verification System Classes	ERC/ARA Code	ARA Description	ODFW Code	ODFW Description	NWI Code	NWI Description
1	Riparian forested	*	hardwood or mixed forest	21, 463, 463.3	Cottonwood, Ash - Cottonwood - bottomland Pasture Mosaic	R	Riverine
2	Forested depression	*	hardwood or mixed forest	21, 463, 463.3	Cottonwood, Ash - Cottonwood - bottomland Pasture Mosaic	PFO	Palustrine Forested
3	Riparian shrub	15	wet shrub	20, 22	Willow, Black Hawthorn, Hedgerows and Brushy Fields -	R	Riverine
4	Wet shrub depression	15	wet shrub	20, 22	Willow, Black Hawthorn, Hedgerows and Brushy Fields -	PSS	Palustrine Scrub Shrub
5	Riparian herbaceous	26,27	Seasonal wetland, permanent wetland, natural grass	30, 31	Cattail - Bulrush, Reed Canary Grass	R	Riverine
6	Seasonal wetland*	26,27	Seasonal wetland, permanent wetland, natural grass	30, 31	Cattail - Bulrush , Reed Canary Grass	P	Palustrine
7	Permanent wetland*	27	permanent wetland	all non-forested wetlands		P	Palustrine
8	Lake	27	Lake, reservoirs, permanent wetlands	9	Water - rivers, lakes and ponds	L	Lacustrine
9	Small stream	28	small stream	9	Water - rivers, lakes and ponds	R	Riverine
10	Large stream	29	large stream	9	Water - rivers, lakes and ponds	R	Riverine
11	Non-wetland						
12	Hetereogeneous**						

*Riparian forest and forested depressions are not distinguished as wetlands by the ERC/ARA classification system. Areas identified as forested wetland in ODFW system will most often be called hardwood or mixed forest in the ERC/ARA system, but not all hardwood forest is wetland.
**More than one type of wetland found within this polygon, or a mixture of wetland/non-wetland cover.

Table 6: Percent total area each classification system found. When the systems were combined in the ordinal or merged map each system found wetlands the others did not find (uniquely identified wetlands). This table represents the additional wetlands found by one system for each system independently as the percent total area each system found in the verification system classes. This table corresponds with figure 10.

Verification System Classes	Classification Systems: ERC/ARA	NWI	ODFW
Riparian forest	10.62	1.22	41.60
Forested depression	4.41	11.36	10.07
Riparian shrub	3.41	0.65	1.30
Wet shrub depression	15.19	19.03	6.94
Riparian herbaceous	3.53	0.53	10.60
Seasonal wetland	44.63	63.10	13.94
Permanent wetland	0.09	0.77	0.58
Lake	0.00	1.22	0.00
Small stream	0.00	0.00	0.00
Large stream	0.00	0.00	0.34
Non-wetland	7.39	0.00	0.53
Heterogeneous	10.73	2.11	14.11
Total Percent per system	100.00	100.00	100.00

Table 7. Percent of polygons each classification system found. When the systems were combined in the ordinal or merged map each system found wetlands the others systems did not find (uniquely identified wetlands). This table represents the uniquely identified wetlands for each system independently as the percent total polygons each system found in the verification system classes. This table corresponds with Figure 11.

Verification System Classes	Classification Systems: ERC/ARA	NWI	ODFW
Riparian forest	4.07	4.72	15.32
Forested depression	10.86	15.09	18.02
Riparian shrub	6.79	0.94	13.51
Wet shrub depression	23.08	33.96	15.32
Riparian herbaceous	9.95	4.72	12.61
Seasonal wetland	31.67	28.30	11.71
Permanent wetland	0.45	3.77	3.60
Lake	0.00	6.60	0.90
Small stream	0.00	0.00	0.00
Large stream	0.45	0.94	2.70
Non-wetland	5.43	0.00	0.90
Heterogeneous	7.24	0.94	5.41
Total percent per system	100.00	100.00	100.00

Table 8. ODFW Strengths and Weaknesses. Total area (in hectares) of each ODFW class found in each of the verification system classes for the study data set.

Verification System Classes	ODFW Classes: 9	20	21	22	30	463	Totals
Riparian forest	20.58	11.76	0.00	0.00	0.06	435.40	467.80
Forested depression	0.00	50.15	48.12	12.06	0.00	184.66	294.99
Riparian shrub	31.43	3.04	0.00	0.20	1.13	10.45	46.25
Wet shrub depression	2.48	60.49	6.42	3.67	8.71	77.70	159.47
Riparian herbaceous	28.51	22.31	0.00	0.00	45.92	2.41	99.14
Seasonal wetland	5.67	23.96	0.09	0.10	80.96	24.32	135.11
Permanent wetland	4.07	0.24	0.00	1.38	0.00	1.75	7.44
Lake	11.72	6.49	0.00	0.00	0.00	0.12	18.33
Small stream	0.00	0.00	0.00	0.00	0.00	14.46	14.46
Large stream	16.99	0.14	0.00	0.00	0.01	3.67	20.81
Non-wetland	0.31	0.99	0.00	1.95	0.38	3.90	7.53
Heterogeneous	15.70	18.98	3.54	0.00	0.00	90.42	128.63
Totals	137.46	198.54	58.17	19.36	137.17	849.27	1399.96

***ODFW Class descriptions in Table 9, yellow indicates correctly classified.**

Table 9. Strengths and weaknesses of ODFW to find wetlands in relation to the verification system classes. Percent of Total Area found by ODFW as wetlands in each verification system class in the study data set. Percent correct/incorrect reflects a percentage of the total wetlands ODFW found compared to the verification system.

Verification System Classes	ODFW Classes: Water - rivers, lakes and ponds	Willow, Black Hawthorn, Hedgerows and Brushy Fields (20+22)	Cottonwood, Ash - Cottonwood - bottomland Pasture Mosaic (21+463)	Cattail - Bulrush, Reed Canary Grass (30)	Totals
Riparian forest	1.47	0.84	31.10	0.00	33.42
Forested depression	0.00	4.44	16.63	0.00	21.07
Riparian shrub	2.25	0.23	0.75	0.08	54.49
Wet shrub depression	0.18	4.58	6.01	0.62	11.39
Riparian herbaceous	2.04	1.59	0.17	3.28	7.08
Seasonal wetland	0.41	1.72	1.74	5.78	18.47
Permanent wetland	0.29	0.12	0.12	0.00	0.53
Lake	0.84	0.46	0.01	0.00	1.31
Small stream	0.00	0.00	1.03	0.00	1.84
Large stream	1.21	0.01	0.26	0.00	1.49
Non-wetland	0.02	0.21	0.28	0.03	0.54
Heterogeneous	1.12	1.36	6.71	0.00	2.02
Totals	9.82	15.56	64.82	9.80	100.00

***Yellow indicates correctly classified**

Percent correct 63.95

Percent incorrect 36.05

Table 10. ERC/ARA Strengths and Weaknesses. Total area of each ERC/ARA class found in each of the verification system classes for the study data set.

Verification System Classes	ERC/ARA Classes 15	26	27	28	29	Totals
Riparian forest	16.83	2.03	2.74	77.42	11.23	110.24
Forested depression	92.06	5.58	1.09	18.75	8.19	125.66
Riparian shrub	8.89	0.92	0.00	11.17	35.78	56.77
Wet shrub depression	200.05	5.98	2.65	21.63	1.03	231.35
Riparian herbaceous	8.23	1.59	0.00	17.93	17.08	44.83
Seasonal wetland	145.96	8.83	0.00	139.34	6.43	300.56
Permanent wetland	0.74	0.92	0.00	0.50	0.00	2.15
Lake	1.31	0.99	15.41	0.00	1.13	18.83
Small stream	0.00	0.00	0.00	14.46	0.00	14.46
Large stream	0.05	2.41	1.21	3.02	9.16	15.84
Non-wetland	45.85	1.95	0.00	0.00	0.89	48.69
Heterogeneous	48.45	5.56	0.70	4.65	24.24	83.59
Totals	568.42	36.75	23.79	308.86	115.15	1052.98

***ERC/ARA Class descriptions in Table 11, yellow indicates correctly classified.**

Table 11. Strengths and weaknesses of ERC/ARA to find wetlands in relation to the verification system classes. Percent of Total Area found by ERC/ARA as wetlands in each verification system class in the study data set. Percent correct/incorrect reflects a percentage of the total wetlands ERC/ARA found compared to the verification system.

Verification system classes	ERC/ARA Classes: Wet shrub (15)	Seasonal wetlands(26)	Permanent Wetlands, Lakes (27)	Small streams (28)	Large streams (29)	Totals
Riparian forest	1.60	0.19	0.26	7.35	1.07	10.47
Forested depression	8.74	0.53	0.10	1.78	0.78	11.93
Riparian shrub	0.84	0.09	0.00	1.06	3.40	5.39
Wet shrub depression	19.00	0.57	0.25	2.05	0.10	21.97
Riparian herbaceous	0.78	0.15	0.00	1.70	1.62	4.26
Seasonal wetland	13.86	0.84	0.00	13.23	0.61	28.54
Permanent wetland	0.07	0.09	0.00	0.05	0.00	0.20
Lake	0.12	0.09	1.46	0.00	0.11	1.79
Small stream	0.00	0.00	0.00	1.37	0.00	1.37
Large stream	0.00	0.23	0.11	0.29	0.87	1.50
Non-wetland	4.35	0.19	0.00	0.00	0.08	4.62
Heterogeneous	4.60	0.53	0.07	0.44	2.30	7.94
Totals	53.98	3.49	2.26	29.33	10.94	100.00

***Yellow indicates correctly classified**

Percent correct	24.54
Percent incorrect	75.46

Table 12. NWI Strengths and Weaknesses. Total area of each NWI class found in each of the verification system classes for the study data set.

Verification System Classes	NWI Classes: L1ABHh	PAB*	PEM*	PFO*	PSS*	PU*	R*	Totals
Riparian forest	0.00	0.00	0.00	134.24	7.21	4.47	7.33	153.24
Forested depression	2.23	0.00	20.00	221.53	6.32	5.13	0.00	255.20
Riparian shrub	0.00	0.00	0.09	0.20	0.39	0.00	13.99	14.67
Wet shrub depression	0.00	0.65	122.60	74.72	14.15	7.69	0.00	219.81
Riparian herbaceous	0.00	0.00	5.06	3.07	7.17	0.00	0.01	15.31
Seasonal wetland	0.47	0.00	303.88	2.64	1.09	0.96	0.00	309.05
Permanent wetland	0.00	0.00	1.33	2.29	0.00	2.50	0.00	6.12
Lake	0.00	8.74	1.54	0.00	0.00	15.71	0.25	26.24
Small stream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large stream	0.00	0.00	0.00	0.00	0.02	0.02	12.69	12.74
Non-wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heterogeneous	0.00	0.00	12.91	1.44	0.00	0.00	12.27	26.62
Totals	2.70	9.39	467.41	440.13	36.35	36.50	46.55	1039.02

*NWI Class descriptions in Table 13, yellow indicates correctly classified.

Table 13. Strengths and weaknesses of NWI to find wetlands in relation to the verification system classes. Percent of Total Area found by NWI as wetlands in each verification system class in the study data set. Percent correct/incorrect reflects a percentage of the total wetlands NWI found compared to the verification system.

Verification system classes	NWI Classes: Lacustrine Limnetic	Palustrine Acquatic Bed	Palustrine Emergent	Palustrine Forested	Palustrine Scrub Shrub	Palustrine Unconsolidated Bottomland	Riverine	Totals
Riparian forest	0.00	0.00	0.00	12.92	0.69	0.43	0.71	14.75
Forested depression	0.21	0.00	1.92	21.32	0.61	0.49	0.00	24.56
Riparian shrub	0.00	0.00	0.01	0.02	0.04	0.00	1.35	1.41
Wet shrub depression	0.00	0.06	11.80	7.19	1.36	0.74	0.00	21.15
Riparian herbaceous	0.00	0.00	0.49	0.30	0.69	0.00	0.00	1.47
Seasonal wetland	0.05	0.00	29.24	0.25	0.11	0.09	0.00	29.74
Permanent wetland	0.00	0.00	0.13	0.22	0.00	0.24	0.00	0.59
Lake	0.00	0.84	0.15	0.00	0.00	1.51	0.02	2.52
Small stream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Large stream	0.00	0.00	0.00	0.00	0.00	0.00	1.22	1.23
Non-wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heterogeneous	0.00	0.00	1.24	0.14	0.00	0.00	1.18	2.56
Totals	0.26	0.90	44.98	42.35	3.50	3.51	4.48	100.00

*Yellow indicates correctly classified

Percent correct	55.66
Percent incorrect	44.33